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1. algorithm

#include <algorithm> #include <numeric>

Algo	Params	Funcion
sort, stable_sort	f, l	ordena el intervalo
nth_element	f, nth, l	void ordena el n-esimo, y particiona el resto
fill, fill_n	f, l / n, elem	void llena [f, l) o [f, f+n) con elem
lower_bound, upper_bound	f, l, elem	it al primer / ultimo donde se puede insertar elem para que quede ordenada
binary_search	f, l, elem	bool esta elem en [f, l)
copy	f, l, resul	hace resul+i=f+i $\forall i$
find, find_if, find_first_of	f, l, elem / pred / f2, l2	it encuentra i $\in [f, l)$ tq. i=elem, pred(i), i $\in [f2, l2)$
count, count_if	f, l, elem/pred	cuenta elem, pred(i)
search	f, l, f2, l2	busca [f2, l2) $\in [f, l)$
replace, replace_if	f, l, old / pred, new	cambia old / pred(i) por new
reverse	f, l	da vuelta
partition, stable_partition	f, l, pred	pred(i) ad, !pred(i) atras
min_element, max_element	f, l, [comp]	it min, max de [f, l)
lexicographical_compare	f1, l1, f2, l2	bool con [f1, l1] i [f2, l2]
next/prev_permutation	f, l	deja en [f, l) la perm sig, ant
set_intersection, set_difference, set_union, set_symmetric_difference,	f1, l1, f2, l2, res	[res, ...) la op. de conj
push_heap, pop_heap, make_heap	f, l, e / e /	mete/saca e en heap [f, l), hace un heap de [f, l)
is_heap	f, l	bool es [f, l) un heap
accumulate	f, l, i, [op]	$T = \sum / \text{oper de } [f, l)$
inner_product	f1, l1, f2, i	$T = i + [f1, l1) \cdot [f2, \dots)$
partial_sum	f, l, r, [op]	$r+i = \sum / \text{oper de } [f, f+i] \forall i \in [f, l)$
__builtin_ffs	unsigned int	Pos. del primer 1 desde la derecha
__builtin_clz	unsigned int	Cant. de ceros desde la izquierda.
__builtin_ctz	unsigned int	Cant. de ceros desde la derecha.
__builtin_popcount	unsigned int	Cant. de 1's en x.
__builtin_parity	unsigned int	1 si x es par, 0 si es impar.
__builtin_XXXXXXll	unsigned ll	= pero para long long's.

2. Estructuras

2.1. RMQ (static)

Dado un arreglo y una operación asociativa *idempotente*, get(i, j) opera sobre el rango [i, j). Restricción: $LVL \geq \text{ceil}(\log n)$; Usar [] para llenar arreglo y luego build().

```

1 struct RMQ{
2     #define LVL 10
3     tipo vec[LVL] [1<<(LVL+1)];
4     tipo &operator[] (int p){return vec[0] [p];}
5     tipo get(int i, int j) {//intervalo [i,j)
6         int p = 31-__builtin_clz(j-i);
7         return min(vec[p] [i], vec[p] [j-(1<<p)]);
8     }
9     void build(int n) {//O(nlogn)
10        int mp = 31-__builtin_clz(n);
11        forn(p, mp) forn(x, n-(1<<p))
12            vec[p+1] [x] = min(vec[p] [x], vec[p] [x+(1<<p)]);
13    }
14 };

```

2.2. RMQ (dynamic)

```

1 //Dado un arreglo y una operacion asociativa con neutro, get(i, j) opera
   sobre el rango [i, j).
2 #define MAXN 100000
3 #define operacion(x, y) max(x, y)
4 const int neutro=0;
5 struct RMQ{
6     int sz;
7     tipo t[4*MAXN];
8     tipo &operator[] (int p){return t[sz+p];}
9     void init(int n){//O(nlgn)
10        sz = 1 << (32-__builtin_clz(n));
11        forr(i, sz, 2*sz) t[i]=neutro;
12    }
13     void updall(){//O(n)
14        dforr(i, sz) t[i]=operacion(t[2*i], t[2*i+1]);}
15     tipo get(int i, int j){return get(i, j, 1, 0, sz);}
16     tipo get(int i, int j, int n, int a, int b){//O(lgn)
17         if(j<=a || i>=b) return neutro;
18         if(i<=a && b<=j) return t[n];

```

```

19     int c=(a+b)/2;
20     return operacion(get(i, j, 2*n, a, c), get(i, j, 2*n+1, c, b));
21 }
22 void set(int p, tipo val){//O(lgn)
23     for(p+=sz; p>0 && t[p]!=val;){
24         t[p]=val;
25         p/=2;
26         val=operacion(t[p*2], t[p*2+1]);
27     }
28 }
29 }rmq;
30 //Usage:
31 cin >> n; rmq.init(n); forn(i, n) cin >> rmq[i]; rmq.updall();

```

2.3. RMQ (lazy)

```

1 //Dado un arreglo y una operacion asociativa con neutro, get(i, j) opera
  sobre el rango [i, j].
2 typedef int Elem; //Elem de los elementos del arreglo
3 typedef int Alt; //Elem de la alteracion
4 #define operacion(x,y) x+y
5 const Elem neutro=0; const Alt neutro2=0;
6 #define MAXN 100000
7 struct RMQ{
8     int sz;
9     Elem t[4*MAXN];
10    Alt dirty[4*MAXN]; //las alteraciones pueden ser de distinto Elem
11    Elem &operator[](int p){return t[sz+p];}
12    void init(int n){//O(nlgn)
13        sz = 1 << (32-__builtin_clz(n));
14        forr(i, sz, 2*sz) t[i]=neutro;
15        forn(i, 2*sz) dirty[i]=neutro2;
16    }
17    void push(int n, int a, int b){//propaga el dirty a sus hijos
18        if(dirty[n]!=0){
19            t[n]+=dirty[n]*(b-a); //altera el nodo
20            if(n<sz){
21                dirty[2*n]+=dirty[n];
22                dirty[2*n+1]+=dirty[n];
23            }
24            dirty[n]=0;
25        }
26    }

```

```

27 Elem get(int i, int j, int n, int a, int b){//O(lgn)
28     if(j<=a || i>=b) return neutro;
29     push(n, a, b); //corrige el valor antes de usarlo
30     if(i<=a && b<=j) return t[n];
31     int c=(a+b)/2;
32     return operacion(get(i, j, 2*n, a, c), get(i, j, 2*n+1, c, b));
33 }
34 Elem get(int i, int j){return get(i,j,1,0,sz);}
35 //altera los valores en [i, j] con una alteracion de val
36 void alterar(Alt val, int i, int j, int n, int a, int b){//O(lgn)
37     push(n, a, b);
38     if(j<=a || i>=b) return;
39     if(i<=a && b<=j){
40         dirty[n]+=val;
41         push(n, a, b);
42         return;
43     }
44     int c=(a+b)/2;
45     alterar(val, i, j, 2*n, a, c), alterar(val, i, j, 2*n+1, c, b);
46     t[n]=operacion(t[2*n], t[2*n+1]); //por esto es el push de arriba
47 }
48 void alterar(Alt val, int i, int j){alterar(val,i,j,1,0,sz);}
49 }rmq;

```

2.4. Fenwick Tree

```

1 //For 2D threat each column as a Fenwick tree, by adding a nested for in
  each operation
2 struct Fenwick{
3     static const int sz=1000001;
4     tipo t[sz];
5     void adjust(int p, tipo v){//valid with p in [1, sz), O(lgn)
6         for(; p<sz; p+=(p&-p)) t[p]+=v; }
7     tipo sum(int p){//cumulative sum in [1, p], O(lgn)
8         tipo s=0;
9         for(; p; p=(p&-p)) s+=t[p];
10        return s;
11    }
12    tipo sum(int a, int b){return sum(b)-sum(a-1);}
13    //get largest value with cumulative sum less than or equal to x;
14    //for smallest, pass x-1 and add 1 to result
15    int getind(tipo x) { //O(lgn)
16        int idx = 0, mask = N;

```

```

17     while(mask && idx < N) {
18         int t = idx + mask;
19         if(x >= tree[t])
20             idx = t, x -= tree[t];
21         mask >>= 1;
22     }
23     return idx;
24 }
25 };

```

2.5. Union Find

```

1 struct UnionFind{
2     vector<int> f; //the array contains the parent of each node
3     void init(int n){f.clear(); f.insert(f.begin(), n, -1);}
4     int comp(int x){return (f[x]==-1?x:f[x]=comp(f[x]));} //O(1)
5     bool join(int i, int j) {
6         bool con=comp(i)==comp(j);
7         if(!con) f[comp(i)] = comp(j);
8         return con;
9     }
10 };

```

2.6. Disjoint Intervals

```

1 bool operator< (const ii &a, const ii &b) {return a.fst<b.fst;}
2 //Stores intervals as [first, second]
3 //in case of a collision it joins them in a single interval
4 struct disjoint_intervals {
5     set<ii> segs;
6     void insert(ii v) { //O(lgn)
7         if(v.snd-v.fst==0.) return; //OJO
8         set<ii>::iterator it, at;
9         at = it = segs.lower_bound(v);
10        if (at!=segs.begin() && (--at)->snd >= v.fst)
11            v.fst = at->fst, --it;
12        for(; it!=segs.end() && it->fst <= v.snd; segs.erase(it++))
13            v.snd=max(v.snd, it->snd);
14        segs.insert(v);
15    }
16 };

```

2.7. RMQ (2D)

```

1 struct RMQ2D{
2     static const int sz=1024;
3     RMQ t[sz];
4     RMQ &operator[] (int p){return t[sz/2+p];}
5     void build(int n, int m){ //O(nm)
6         forr(y, sz/2, sz/2+m)
7             t[y].build(m);
8         forr(y, sz/2+m, sz)
9             forn(x, sz)
10                t[y].t[x]=0;
11         dforn(y, sz/2)
12             forn(x, sz)
13                t[y].t[x]=max(t[y*2].t[x], t[y*2+1].t[x]);
14    }
15     void set(int x, int y, tipo v){ //O(lgm.lgn)
16         y+=sz/2;
17         t[y].set(x, v);
18         while(y/=2)
19             t[y].set(x, max(t[y*2][x], t[y*2+1][x]));
20    }
21     //O(lgm.lgn)
22     int get(int x1, int y1, int x2, int y2, int n=1, int a=0, int b=sz/2){
23         if(y2<=a || y1>=b) return 0;
24         if(y1<=a && b<=y2) return t[n].get(x1, x2);
25         int c=(a+b)/2;
26         return max(get(x1, y1, x2, y2, 2*n, a, c),
27                    get(x1, y1, x2, y2, 2*n+1, c, b));
28    }
29 };
30 //Example to initialize a grid of M rows and N columns:
31 RMQ2D rmq;
32 forn(i, M)
33     forn(j, N)
34         cin >> rmq[i][j];
35 rmq.build(N, M);

```

2.8. Big Int

```

1 #define BASEXP 6
2 #define BASE 1000000
3 #define LMAX 1000
4 struct bint{
5     int l;

```

```

6     ll n[LMAX];
7     bint(ll x=0){
8         l=0;
9         forn(i, LMAX){
10             n[i]=x%BASE;
11             x/=BASE;
12             l+=!!x||!i;
13         }
14     }
15     bint(string x){
16         l=(x.size()-1)/BASEXP+1;
17         fill(n, n+LMAX, 0);
18         ll r=1;
19         forn(i, sz(x)){
20             n[i / BASEXP] += r * (x[x.size()-1-i]-'0');
21             r*=10; if(r==BASE)r=1;
22         }
23     }
24     void out(){
25         cout << n[l-1];
26         dforn(i, l-1) printf("%6.6llu", n[i]); //6=BASEXP!
27     }
28     void invar(){
29         fill(n+l, n+LMAX, 0);
30         while(l>1 && !n[l-1]) l--;
31     }
32 };
33 bint operator+(const bint&a, const bint&b){
34     bint c;
35     c.l = max(a.l, b.l);
36     ll q = 0;
37     forn(i, c.l) q += a.n[i]+b.n[i], c.n[i]=q %BASE, q/=BASE;
38     if(q) c.n[c.l++] = q;
39     c.invar();
40     return c;
41 }
42 pair<bint, bool> lresta(const bint& a, const bint& b) // c = a - b
43 {
44     bint c;
45     c.l = max(a.l, b.l);
46     ll q = 0;
47     forn(i, c.l) q += a.n[i]-b.n[i], c.n[i]=(q+BASE) %BASE, q=(q+BASE)/
        BASE-1;

```

```

48     c.invar();
49     return make_pair(c, !q);
50 }
51 bint& operator-= (bint& a, const bint& b){return a=lresta(a, b).first;}
52 bint operator- (const bint&a, const bint&b){return lresta(a, b).first;}
53 bool operator< (const bint&a, const bint&b){return !lresta(a, b).second;
54 };}
54 bool operator<= (const bint&a, const bint&b){return lresta(b, a).second;
55 };}
55 bool operator==(const bint&a, const bint&b){return a <= b && b <= a;}
56 bint operator*(const bint&a, ll b){
57     bint c;
58     ll q = 0;
59     forn(i, a.l) q += a.n[i]*b, c.n[i] = q %BASE, q/=BASE;
60     c.l = a.l;
61     while(q) c.n[c.l++] = q %BASE, q/=BASE;
62     c.invar();
63     return c;
64 }
65 bint operator*(const bint&a, const bint&b){
66     bint c;
67     c.l = a.l+b.l;
68     fill(c.n, c.n+b.l, 0);
69     forn(i, a.l){
70         ll q = 0;
71         forn(j, b.l) q += a.n[i]*b.n[j]+c.n[i+j], c.n[i+j] = q %BASE, q
            /=BASE;
72         c.n[i+b.l] = q;
73     }
74     c.invar();
75     return c;
76 }
77 pair<bint, ll> ldiv(const bint& a, ll b){// c = a / b ; rm = a % b
78     bint c;
79     ll rm = 0;
80     dforn(i, a.l){
81         rm = rm * BASE + a.n[i];
82         c.n[i] = rm / b;
83         rm %= b;
84     }
85     c.l = a.l;
86     c.invar();
87     return make_pair(c, rm);

```

```

88 }
89 bint operator/(const bint&a, ll b){return ldiv(a, b).first;}
90 ll operator%(const bint&a, ll b){return ldiv(a, b).second;}
91 pair<bint, bint> ldiv(const bint& a, const bint& b){
92     bint c;
93     bint rm = 0;
94     dforn(i, a.l){
95         if (rm.l==1 && !rm.n[0])
96             rm.n[0] = a.n[i];
97         else{
98             dforn(j, rm.l) rm.n[j+1] = rm.n[j];
99             rm.n[0] = a.n[i];
100             rm.l++;
101         }
102         ll q = rm.n[b.l] * BASE + rm.n[b.l-1];
103         ll u = q / (b.n[b.l-1] + 1);
104         ll v = q / b.n[b.l-1] + 1;
105         while (u < v-1){
106             ll m = (u+v)/2;
107             if (b*m <= rm) u = m;
108             else v = m;
109         }
110         c.n[i]=u;
111         rm-=b*u;
112     }
113     c.l=a.l;
114     c.invar();
115     return make_pair(c, rm);
116 }
117 bint operator/(const bint&a, const bint&b){return ldiv(a, b).first;}
118 bint operator%(const bint&a, const bint&b){return ldiv(a, b).second;}

```

2.9. Modnum

```

1 struct mnum{
2     static const tipo mod=12582917;
3     tipo v;
4     mnum(tipo v=0): v(v%mod) {}
5     mnum operator+(mnum b){return v+b.v;}
6     mnum operator-(mnum b){return v>=b.v? v-b.v : mod-b.v+v;}
7     mnum operator*(mnum b){return v*b.v;}
8     mnum operator^(int n){
9         if(!n) return 1;

```

```

10     return n%2? (*this)^(n/2)*(*this) : (*this)^(n/2);}
11 };

```

2.10. Treap

```

1 typedef int Key;
2
3 typedef struct node *pnode;
4 struct node{
5     Key key;
6     int prior, size;
7     pnode l,r;
8     node(Key key=0, int prior=0): key(key), prior(prior), size(1), l(0),
9         r(0) {}
10 };
11 struct treap {
12     pnode root;
13     treap(): root(0) {}
14     int size(pnode p) { return p ? p->size : 0; }
15     int size() { return size(root); }
16     void push(pnode p) {
17         // modificar y propagar el dirty a los hijos aca(para lazy)
18     }
19     // Update function and size from children's values
20     void pull(pnode p) { //recalcular valor del nodo aca (para rmq)
21         p->size = 1 + size(p->l) + size(p->r);
22     }
23     pnode merge(pnode l, pnode r) {
24         if (!l || !r) return l ? l : r;
25         push(l), push(r);
26         pnode t;
27         if (l->prior < r->prior) l->r=merge(l->r, r), t = l;
28         else r->l=merge(l, r->l), t = r;
29         pull(t);
30         return t;
31     } //opcional:
32     void merge(treap t) {root = merge(root, t.root), t.root=0;}
33     //*****KEY OPERATIONS*****//
34     void splitKey(pnode t, Key key, pnode &l, pnode &r) {
35         if (!t) return void(l = r = 0);
36         push(t);
37         if (key <= t->key) splitKey(t->l, key, l, t->l), r = t;
38         else splitKey(t->r, key, t->r, r), l = t;

```

```

38     pull(t);
39 }
40 void insertKey(Key key) {
41     pnode elem = new node(key, rand());
42     pnode t1, t2; splitKey(root, key, t1, t2);
43     t1=merge(t1,elem);
44     root=merge(t1,t2);
45 }
46 void eraseKeys(Key key1, Key key2) {
47     pnode t1,t2,t3;
48     splitKey(root,key1,t1,t2);
49     splitKey(t2,key2, t2, t3);
50     root=merge(t1,t3);
51 }
52 void eraseKey(pnode &t, Key key) {
53     if (!t) return;
54     push(t);
55     if (key == t->key) t=merge(t->l, t->r);
56     else if (key < t->key) eraseKey(t->l, key);
57     else eraseKey(t->r, key);
58     pull(t);
59 }
60 void eraseKey(Key key) {eraseKey(root, key);}
61 pnode findKey(pnode t, Key key) {
62     if (!t) return 0;
63     if (key == t->key) return t;
64     if (key < t->key) return findKey(t->l, key);
65     return findKey(t->r, key);
66 }
67 pnode findKey(Key key) { return findKey(root, key); }
68 //*****POS OPERATIONS*****// No mezclar con las funciones Key
69 //(No funciona con pos:)
70 void splitSize(pnode t, int sz, pnode &l, pnode &r) {
71     if (!t) return void(l = r = 0);
72     push(t);
73     if (sz <= size(t->l)) splitSize(t->l, sz, l, t->l), r = t;
74     else splitSize(t->r, sz - 1 - size(t->l), t->r, r), l = t;
75     pull(t);
76 }
77 void insertPos(int pos, Key key) {
78     pnode elem = new node(key, rand());
79     pnode t1,t2; splitSize(root, pos, t1, t2);
80     t1=merge(t1,elem);

```

```

81     root=merge(t1,t2);
82 }
83 void erasePos(int pos1, int pos2=-1) {
84     if(pos2==-1) pos2=pos1+1;
85     pnode t1,t2,t3;
86     splitSize(root,pos1,t1,t2);
87     splitSize(t2,pos2-pos1,t2,t3);
88     root=merge(t1, t2);
89 }
90 pnode findPos(pnode t, int pos) {
91     if(!t) return 0;
92     if(pos <= size(t->l)) return findPos(t->l, pos);
93     return findPos(t->r, pos - 1 - size(t->l));
94 }
95 Key &operator[](int pos){return findPos(root, pos)->key;}//ojito
96 };

```

2.11. Gain-Cost Set

```

1 //esta estructura mantiene pairs(beneficio, costo)
2 //de tal manera que en el set quedan ordenados
3 //por beneficio Y COSTO creciente. (va borrando los que no son optimos)
4 struct V{
5     int gain, cost;
6     bool operator<(const V &b)const{return gain<b.gain;}
7 };
8 set<V> s;
9 void add(V x){
10     set<V>::iterator p=s.lower_bound(x);//primer elemento mayor o igual
11     if(p!=s.end() && p->cost <= x.cost) return;//ya hay uno mejor
12     p=s.upper_bound(x);//primer elemento mayor
13     if(p!=s.begin()){//borro todos los peores (<=beneficio y >=costo)
14         --p;//ahora es ultimo elemento menor o igual
15         while(p->cost >= x.cost){
16             if(p==s.begin()){s.erase(p); break;}
17             s.erase(p--);
18         }
19     }
20     s.insert(x);
21 }
22 int get(int gain){//minimo costo de obtener tal ganancia
23     set<V>::iterator p=s.lower_bound((V){gain, 0});
24     return p==s.end()? INF : p->cost;}

```


3. Algos

3.1. Longest Increasing Subsequence

```

1 //Para non-increasing, cambiar comparaciones y revisar busq binaria
2 //Given an array, paint it in the least number of colors so that each
  color turns to a non-increasing subsequence.
3 //Solution:Min number of colors=Length of the longest increasing
  subsequence
4 int N, a[MAXN]; //secuencia y su longitud
5 ii d[MAXN+1]; //d[i]=ultimo valor de la subsecuencia de tamaño i
6 int p[MAXN]; //padres
7 vector<int> R; //respuesta
8 void rec(int i){
9     if(i== -1) return;
10    R.push_back(a[i]);
11    rec(p[i]);
12 }
13 int lis(){ //O(nlogn)
14     d[0] = ii(-INF, -1); forn(i, N) d[i+1]=ii(INF, -1);
15     forn(i, N){
16         int j = upper_bound(d, d+N+1, ii(a[i], INF))-d;
17         if (d[j-1].first < a[i] && a[i] < d[j].first){
18             p[i]=d[j-1].second;
19             d[j] = ii(a[i], i);
20         }
21     }
22     R.clear();
23     dforn(i, N+1) if(d[i].first!=INF){
24         rec(d[i].second); //reconstruir
25         reverse(R.begin(), R.end());
26         return i; //longitud
27     }
28     return 0;
29 }

```

4. Strings

4.1. KMP

```

1 string T; //cadena donde buscar(where)
2 string P; //cadena a buscar(what)
3 int b[MAXLEN]; //back table

```

```

4 void kmppre(){ //by gabina with love
5     int i =0, j=-1; b[0]=-1;
6     while(i<sz(P)){
7         while(j>=0 && P[i] != P[j]) j=b[j];
8         i++, j++;
9         b[i] = j;
10    }
11 }
12
13 void kmp(){
14     int i=0, j=0;
15     while(i<sz(T)){
16         while(j>=0 && T[i]!=P[j]) j=b[j];
17         i++, j++;
18         if(j==sz(P)){
19             printf("P is found at index %d in T\n", i-j);
20             j=b[j];
21         }
22     }
23 }

```

4.2. Trie

```

1 struct trie{
2     map<char, trie> m;
3     void add(const string &s, int p=0){
4         if(s[p]) m[s[p]].add(s, p+1);
5     }
6     void dfs(){
7         //Do stuff
8         forall(it, m)
9             it->second.dfs();
10    }
11 };

```

4.3. Suffix Array (corto, nlog2n)

```

1 pair<int, int> sf[MAXN];
2 bool comp(int lhs, int rhs) {return sf[lhs] < sf[rhs];}
3 struct SuffixArray {
4     //sa guarda los indices de los sufijos ordenados
5     int sa[MAXN], r[MAXN];
6     void init(const char *a, int n) {
7         forn(i, n) r[i] = a[i];

```



```

8     for(int m = 1; m < n; m <= 1) {
9         forn(i, n) sa[i]=i, sf[i] = make_pair(r[i], i+m<n? r[i+m]:-1);
10        stable_sort(sa, sa+n, comp);
11        r[sa[0]] = 0;
12        forr(i, 1, n) r[sa[i]] = sf[sa[i]] != sf[sa[i-1]] ? i : r[
            sa[i-1]];
13    }
14 }
15 } sa;

```

4.4. Suffix Array (largo, nlogn)

```

1 #define MAX_N 1000
2 #define rBOUND(x) (x<n? r[x] : 0)
3 //sa will hold the suffixes in order.
4 int sa[MAX_N], r[MAX_N], n;
5 string s; //input string, n=sz(s)
6
7 void countingSort(int k){
8     int f[MAX_N], tmpsa[MAX_N];
9     zero(f);
10    forn(i, n) f[rBOUND(i+k)]++;
11    int sum=0;
12    forn(i, max(255, n)){
13        int t=f[i]; f[i]=sum; sum+=t;}
14    forn(i, n)
15        tmpsa[f[rBOUND(sa[i]+k)]++] = sa[i];
16    memcpy(sa, tmpsa, sizeof(sa));
17 }
18 void constructsa(){//O(n log n)
19     n=sz(s);
20     forn(i, n) sa[i]=i, r[i]=s[i];
21     for(int k=1; k<n; k<=1){
22         countingSort(k), countingSort(0);
23         int rank, tmpr[MAX_N];
24         tmpr[sa[0]]=rank=0;
25         forr(i, 1, n)
26             tmpr[sa[i]]=(r[sa[i]]==r[sa[i-1]] && r[sa[i]+k]==r[sa[i-1]+k])?
                rank : ++rank;
27         memcpy(r, tmpr, sizeof(r));
28         if(r[sa[n-1]]==n-1) break;
29     }
30 }

```

```

31 void print(){//for debug
32     forn(i, n)
33         cout << i << ' ' <<
34         s.substr(sa[i], s.find( '$', sa[i])-sa[i]) << endl;}

```

4.5. String Matching With Suffix Array

```

1 //returns (lowerbound, upperbound) of the search
2 ii stringMatching(string P){ //O(sz(P)lgn)
3     int lo=0, hi=n-1, mid=lo;
4     while(lo<hi){
5         mid=(lo+hi)/2;
6         int res=s.compare(sa[mid], sz(P), P);
7         if(res>=0) hi=mid;
8         else lo=mid+1;
9     }
10    if(s.compare(sa[lo], sz(P), P)!=0) return ii(-1, -1);
11    ii ans; ans.fst=lo;
12    lo=0, hi=n-1, mid;
13    while(lo<hi){
14        mid=(lo+hi)/2;
15        int res=s.compare(sa[mid], sz(P), P);
16        if(res>0) hi=mid;
17        else lo=mid+1;
18    }
19    if(s.compare(sa[hi], sz(P), P)!=0) hi--;
20    ans.snd=hi;
21    return ans;
22 }

```

4.6. LCP (Longest Common Prefix)

```

1 //Calculates the LCP between consecutives suffixes in the Suffix Array.
2 //LCP[i] is the length of the LCP between sa[i] and sa[i-1]
3 int LCP[MAX_N], phi[MAX_N], PLCP[MAX_N];
4 void computeLCP(){//O(n)
5     phi[sa[0]]=-1;
6     forr(i, 1, n) phi[sa[i]]=sa[i-1];
7     int L=0;
8     forn(i, n){
9         if(phi[i]==-1) {PLCP[i]=0; continue;}
10        while(s[i+L]==s[phi[i]+L]) L++;
11        PLCP[i]=L;
12        L=max(L-1, 0);

```

```

13 }
14 forn(i, n) LCP[i]=PLCP[sa[i]];
15 }

```

4.7. Corasick

```

1 struct trie{
2     map<char, trie> next;
3     trie* tran[256]; //transiciones del automata
4     int idhoja, szhoja; //id de la hoja o 0 si no lo es
5     //link lleva al sufijo mas largo, nxthoja lleva al mas largo pero que
6     //es hoja
7     trie *padre, *link, *nxthoja;
8     char pch; //caracter que conecta con padre
9     trie(): tran(), idhoja(), padre(), link() {}
10    void insert(const string &s, int id=1, int p=0){ //id>0!!!
11        if(p<sz(s)){
12            trie &ch=next[s[p]];
13            tran[(int)s[p]]=&ch;
14            ch.padre=this, ch.pch=s[p];
15            ch.insert(s, id, p+1);
16        }
17        else idhoja=id, szhoja=sz(s);
18    }
19    trie* get_link() {
20        if(!link){
21            if(!padre) link=this; //es la raiz
22            else if(!padre->padre) link=padre; //hijo de la raiz
23            else link=padre->get_link()->get_tran(pch);
24        }
25        return link;
26    }
27    trie* get_tran(int c) {
28        if(!tran[c])
29            tran[c] = !padre? this : this->get_link()->get_tran(c);
30        return tran[c];
31    }
32    trie *get_nxthoja(){
33        if(!nxthoja) nxthoja = get_link()->idhoja? link : link->nxthoja;
34        return nxthoja;
35    }
36    void print(int p){

```

```

37        if(idhoja)
38            cout << "found_" << idhoja << "_at_position_" << p-szhoja << endl
39            ;
40        if(get_nxthoja()) get_nxthoja()->print(p);
41    }
42    void matching(const string &s, int p=0){
43        print(p);
44        if(p<sz(s)) get_tran(s[p])->matching(s, p+1);

```

5. Geometría

#define EPS 1e-9

5.1. Punto

```

1 struct pto{
2     tipo x, y;
3     pto(tipo x=0, tipo y=0):x(x),y(y){}
4     pto operator+(pto a){return pto(x+a.x, y+a.y);}
5     pto operator-(pto a){return pto(x-a.x, y-a.y);}
6     pto operator+(tipo a){return pto(x+a, y+a);}
7     pto operator*(tipo a){return pto(x*a, y*a);}
8     pto operator/(tipo a){return pto(x/a, y/a);}
9     //dot product, producto interno:
10    tipo operator*(pto a){return x*a.x+y*a.y;}
11    //module of the cross product or vectorial product:
12    //if a is less than 180 clockwise from b, a^b>0
13    tipo operator^(pto a){return x*a.y-y*a.x;}
14    //returns true if this is at the left side of line qr
15    bool left(pto q, pto r){return ((q-*this)^(r-*this))>0;}
16    bool operator<(const pto &a) const{return x<a.x || (abs(x-a.x)<EPS &&
17        y<a.y);}
18    bool operator==(pto a){return abs(x-a.x)<EPS && abs(y-a.y)<EPS;}
19    double norm(){return sqrt(x*x+y*y);}
20    tipo norm_sq(){return x*x+y*y;}
21 };
22 double dist(pto a, pto b){return (b-a).norm();}
23 typedef pto vec;
24 double angle(pto a, pto o, pto b){
25     vec oa=a-o, ob=b-o;
26     return acos((oa*ob) / sqrt(oa.norm_sq()*ob.norm_sq()));}
27

```

```

28 //rotate p by theta rads CCW w.r.t. origin (0,0)
29 pto rotate(pto p, double theta){
30     return pto(p.x*cos(theta)-p.y*sin(theta),
31         p.x*sin(theta)+p.y*cos(theta));
32 }

```

5.2. Line

```

1 struct line{
2     line() {}
3     double a,b,c;//Ax+By=C
4     //pto MUST store float coordinates!
5     line(double a, double b, double c):a(a),b(b),c(c){}
6     line(pto p, pto q): a(q.y-p.y), b(p.x-q.x), c(a*p.x+b*p.y) {}
7 };
8 bool parallels(line l1, line l2){return abs(l1.a*l2.b-l2.a*l1.b)<EPS;}
9 pto inter(line l1, line l2){//intersection
10     double det=l1.a*l2.b-l2.a*l1.b;
11     if(abs(det)<EPS) return pto(INF, INF);//parallels
12     return pto(l2.b*l1.c-l1.b*l2.c, l1.a*l2.c-l2.a*l1.c)/det;
13 }

```

5.3. Segment

```

1 struct segm{
2     pto s,f;
3     segm(pto s, pto f):s(s), f(f) {}
4     pto closest(pto p) {//use for dist to point
5         double l2 = dist_sq(s, f);
6         if(l2==0.) return s;
7         double t=((p-s)*(f-s))/l2;
8         if (t<0.) return s;//not write if is a line
9         else if(t>1.)return f;//not write if is a line
10        return s+((f-s)*t);
11    }
12    bool inside(pto p){
13        return ((s-p)^(f-p))==0 && min(s, f)<=this->s<=this->f;
14    };
15
16    bool insidebox(pto a, pto b, pto p) {
17        return (a.x-p.x)*(p.x-b.x)>=EPS && (a.y-p.y)*(p.y-b.y)>=EPS;
18    }
19    pto inter(segm s1, segm s2){
20        pto r=inter(line(s1.s, s1.f), line(s2.s, s2.f));

```

```

21     if(insidebox(s1.s,s1.f,p) && insidebox(s2.s,s2.f,p))
22         return r;
23     return pto(INF, INF);
24 }

```

5.4. Rectangle

```

1 struct rect{
2     //lower-left and upper-right corners
3     pto lw, up;
4 };
5 //returns if there's an intersection and stores it in r
6 bool inter(rect a, rect b, rect &r){
7     r.lw=pto(max(a.lw.x, b.lw.x), max(a.lw.y, b.lw.y));
8     r.up=pto(min(a.up.x, b.up.x), min(a.up.y, b.up.y));
9     //check case when only a edge is common
10    return r.lw.x<r.up.x && r.lw.y<r.up.y;
11 }

```

5.5. Polygon Area

```

1 double area(vector<tipo> &p){//0(sz(p))
2     double area=0;
3     forn(i, sz(p)) area+=p[i]^p[(i+1)%sz(p)];
4     //if points are in clockwise order then area is negative
5     return abs(area)/2;
6 }
7 //Area ellipse = M_PI*a*b where a and b are the semi axis lengths
8 //Area triangle = sqrt(s*(s-a)(s-b)(s-c)) where s=(a+b+c)/2

```

5.6. Circle

```

1 vec perp(vec v){return vec(-v.y, v.x);}
2 line bisector(pto x, pto y){
3     line l=line(x, y); pto m=(x+y)/2;
4     return line(-l.b, l.a, -l.b*m.x+l.a*m.y);
5 }
6 struct Circle{
7     pto o;
8     double r;
9     //circle determined by three points, uses line
10    Circle(pto x, pto y, pto z){
11        o=inter(bisector(x, y), bisector(y, z));
12        r=dist(o, x);

```

```

13 }
14 pair<pto, pto> ptosTang(pto p){
15     pto m=(p+o)/2;
16     tipo d=dist(o, m);
17     tipo a=r*r/(2*d);
18     tipo h=sqrt(r*r-a*a);
19     pto m2=o+(m-o)*a/d;
20     vec per=perp(m-o)/d;
21     return mkp(m2-per*h, m2+per*h);
22 }
23 };
24 //finds the center of the circle containing p1 and p2 with radius r
25 //as there may be two solutions swap p1, p2 to get the other
26 bool circle2PtsRad(pto p1, pto p2, double r, pto &c){
27     double d2=(p1-p2).norm_sq(), det=r*r/d2-0.25;
28     if(det<0) return false;
29     c=(p1+p2)/2+perp(p2-p1)*sqrt(det);
30     return true;
31 }

```

5.7. Point in Poly

```

1 //checks if v is inside of P, using ray casting
2 //works with convex and concave.
3 //excludes boundaries, handle it separately using segment.inside()
4 bool inPolygon(pto v, vector<pto>& P) {
5     bool c = false;
6     forn(i, sz(P)){
7         int j=(i+1)%sz(P);
8         if((P[j].y>v.y) != (P[i].y > v.y) &&
9         (v.x < (P[i].x - P[j].x) * (v.y-P[j].y) / (P[i].y - P[j].y) + P[j].x))
10             c = !c;
11     }
12     return c;
13 }

```

5.8. Convex Check CHECK

```

1 bool isConvex(vector<int> &p){//O(N)
2     int N=sz(p);
3     if(N<3) return false;
4     bool isLeft=p[0].left(p[1], p[2]);
5     forr(i, 1, N)
6         if(p[i].left(p[(i+1)%N], p[(i+2)%N])!=isLeft)

```

```

7     return false;
8     return true; }

```

5.9. Convex Hull

```

1 //stores convex hull of P in S, CCW order
2 void CH(vector<pto>& P, vector<pto> &S){
3     S.clear();
4     sort(P.begin(), P.end());
5     forn(i, sz(P)){
6         while(sz(S)>= 2 && S[sz(S)-1].left(S[sz(S)-2], P[i])) S.pop_back();
7         S.pb(P[i]);
8     }
9     S.pop_back();
10    int k=sz(S);
11    dforr(i, sz(P)){
12        while(sz(S)>= k+2 && S[sz(S)-1].left(S[sz(S)-2], P[i])) S.pop_back
13            ();
14        S.pb(P[i]);
15    }
16    S.pop_back();

```

5.10. Cut Polygon

```

1 //cuts polygon Q along the line ab
2 //stores the left side (swap a, b for the right one) in P
3 void cutPolygon(pto a, pto b, vector<pto> Q, vector<pto> &P){
4     P.clear();
5     forn(i, sz(Q)){
6         double left1=(b-a)^(Q[i]-a), left2=(b-a)^(Q[(i+1)%sz(Q)]-a);
7         if(left1>=0) P.pb(Q[i]);
8         if(left1*left2<0)
9             P.pb(inter(line(Q[i], Q[(i+1)%sz(Q)]), line(a, b)));
10    }
11 }

```

5.11. Bresenham

```

1 //plot a line approximation in a 2d map
2 void bresenham(pto a, pto b){
3     pto d=b-a; d.x=abs(d.x), d.y=abs(d.y);
4     pto s(a.x<b.x? 1: -1, a.y<b.y? 1: -1);
5     int err=d.x-d.y;

```

```

6 while(1){
7     m[a.x][a.y]=1;//plot
8     if(a==b) break;
9     int e2=2*err;
10    if(e2 > -d.y){
11        err=-d.y, a.x+=s.x;
12    }
13    if(e2 < d.x)
14        err+= d.x, a.y+= s.y;
15 }

```

5.12. Rotate Matrix

```

1 //rotates matrix t 90 degrees clockwise
2 //using auxiliary matrix t2(faster)
3 void rotate(){
4     forn(x, n) forn(y, n)
5         t2[n-y-1][x]=t[x][y];
6     memcpy(t, t2, sizeof(t));
7 }

```

6. Math

6.1. Combinatorio

```

1 forn(i, MAXN+1){//comb[i][k]=i tomados de a k
2     comb[i][0]=comb[i][i]=1;
3     forr(k, 1, i) comb[i][k]=(comb[i-1][k]+comb[i-1][k-1])%MOD;
4 }

```

6.2. Exp. de Numeros Mod.

```

1 int expmod (int b, int e){
2     if(!e) return 1;
3     ll q= expmod(b,e/2); q=(q*q)%MOD;
4     return e%2? (b * q)%MOD : q;
5 }

```

6.3. Exp. de Matrices en log(n)

```

1 struct M22{ // |a b|
2     double a,b,c,d;// |c d|
3     M22 operator*(const M22 &p) const {
4         return (M22){a*p.a+b*p.c, a*p.b+b*p.d, c*p.a+d*p.c,c*p.b+d*p.d};}

```

```

5 };
6 M22 operator^(const M22 &p, int n){
7     if(!n) return (M22){1, 0, 0, 1}; //identidad
8     M22 q=p^(n/2); q=q*q;
9     return n%2? p * q : q;}

```

6.4. Phollard's Rho

```

1 ll mulmod (ll a, ll b, ll c) { //returns (a*b)%c, and minimize overflow
2     ll x = 0, y = a%c;
3     while (b > 0){
4         if (b % 2 == 1) x = (x+y) % c;
5         y = (y*2) % c;
6         b /= 2;
7     }
8     return x % c;
9 }
10
11 ll pollard_rho (ll n){
12     int i = 0, k = 2;
13     ll x = 3, y = 3;
14     while (1){
15         i++;
16         x = (mulmod (x,x,n) + n - 1) % n;
17         ll d = gcd (abs(y-x), n);
18         if (d != 1 && d != n) return d;
19         if (i == k) y = x, k*=2;
20     }
21 }
22
23 int main(){
24     ll n = 2063512844981574047LL;
25     ll ans = pollard_rho (n);
26     if (ans > n / ans) ans = n / ans;
27     printf ("%lld, %lld\n", ans, n / ans);
28     return 0;
29 }

```

6.5. Criba

```

1 #define MAXP 80000 //no necesariamente primo
2 int criba[MAXP+1];
3 vector<int> primos;
4 void buscarprimos(){

```

```

5  int sq=sqrt(MAXP)+1;
6  forr(p, 2, MAXP+1) if(!criba[p]){
7      primos.push_back(p);
8      if(p<=sq)
9          for(int m=p*p; m<=MAXP; m+=p)//borro los multiplos de p
10             if(!criba[m])criba[m]=p;
11  }
12 }
```

6.6. Factorizacion

Sea $n = \prod p_i^{k_i}$, fact(n) genera un map donde a cada p_i le asocia su k_i

```

1  //factoriza bien numeros hasta (maximo primo)^2
2  map<ll,ll> fact(ll n){
3      map<ll,ll> ret;
4      forall(p, primos){
5          while(!(n%p)){
6              ret[*p]++;//divisor found
7              n/=p;
8          }
9      }
10     if(n>1) ret[n]++;
11     return ret;
12 }
```

6.7. GCD

```

1  tipo gcd(tipo a, tipo b){return a?gcd(b %a, a):b;}
```

6.8. LCM

```

1  tipo lcm(tipo a, tipo b){return a / gcd(a,b) * b;}
```

6.9. Simpson

```

1  double integral(double a, double b, int n=10000) {//0(n), n=cantdiv
2      double area=0, h=(b-a)/n, fa=f(a), fb;
3      forn(i, n){
4          fb=f(a+h*(i+1));
5          area+=fa+ 4*f(a+h*(i+0.5)) +fb, fa=fb;
6      }
7      return area*h/6.;}
```

6.10. Fraction

```

1  struct frac{
2      tipo p,q;
3      frac(tipo p=0, tipo q=1):p(p),q(q) {norm();}
4      tipo mcd(tipo a, tipo b){return a?mcd(b %a, a):b;}
5      void norm(){
6          tipo a = mcd(p,q);
7          if(a) p/=a, q/=a;
8          else q=1;
9          if (q<0) q=-q, p=-p;}
10     frac operator+(const frac& o){
11         tipo a = mcd(q,o.q);
12         return frac(p*(o.q/a)+o.p*(q/a), q*(o.q/a));}
13     frac operator-(const frac& o){
14         tipo a = mcd(q,o.q);
15         return frac(p*(o.q/a)-o.p*(q/a), q*(o.q/a));}
16     frac operator*(frac o){
17         tipo a = mcd(q,o.p), b = mcd(o.q,p);
18         return frac((p/b)*(o.p/a), (q/a)*(o.q/b));}
19     frac operator/(frac o){
20         tipo a = mcd(q,o.q), b = mcd(o.p,p);
21         return frac((p/b)*(o.q/a), (q/a)*(o.p/b));}
22     bool operator<(const frac &o) const{return p*o.q < o.p*q;}
23     bool operator==(frac o){return p==o.p&&q==o.q;}
24 };
```

6.11. Polinomio

```

1  #define MAX_GR 20
2  struct poly {
3      tipo p[MAX_GR];//guarda los coeficientes del polinomio
4      poly(){zero(p);}
5      int gr(){//calculates grade of the polynomial
6          dform(i,MAX_GR) if(p[i]) return i;
7          return 0; }
8      bool isnull(){return gr()==0 && !p[0];}
9      poly operator+(poly b) {// - is analogous
10         poly c=THIS;
11         forn(i,MAX_GR) c.p[i]+=b.p[i];
12         return c;
13     }
14     poly operator*(poly b) {
```

```

15     poly c;
16     forn(i,MAX_GR) forn(k,i+1) c.p[i]+=p[k]*b.p[i-k];
17     return c;
18 }
19 tipo eval(tipo v) {
20     tipo sum = 0;
21     dforn(i, MAX_GR) sum=sum*v + p[i];
22     return sum;
23 }
24 //the following function generates the roots of the polynomial
25 //it can be easily modified to return float roots
26 set<tipo> roots(){
27     set<tipo> roots;
28     tipo a0 = abs(p[0]), an = abs(p[gr()]);
29     vector<tipo> ps,qs;
30     forr(p,1,sqrt(a0)+1) if (a0%p==0) ps.pb(p),ps.pb(a0/p);
31     forr(q,1,sqrt(an)+1) if (an%q==0) qs.pb(q),qs.pb(an/q);
32     forall(pt,ps)
33         forall(qt,qs) if ( (*pt) % (*qt)==0 ) {
34             tipo root = abs((*pt) / (*qt));
35             if (eval(root)==0) roots.insert(root);
36         }
37     return roots;
38 }
39 };
40 //the following functions allows parsing an expression like
41 //34+150+4*45
42 //into a polynomial(el numero en funcion de la base)
43 #define LAST(s) (sz(s)? s[sz(s)-1] : 0)
44 #define POP(s) s.erase(--s.end());
45 poly D(string &s) {
46     poly d;
47     for(int i=0; isdigit(LAST(s)); i++) d.p[i]=LAST(s)-'0', POP(s);
48     return d;}
49
50 poly T(string &s) {
51     poly t=D(s);
52     if (LAST(s)=='*'){POP(s); return T(s)*t;}
53     return t;
54 }
55 //main function, call this to parse
56 poly E(string &s) {
57     poly e=T(s);

```

```

58     if (LAST(s)=='*'){POP(s); return E(s)+e;}
59     return e;
60 }

```

7. Grafos

7.1. Dijkstra

```

1  #define INF 1e9
2  int N;
3  #define MAX_V 250001
4  vector<ii> G[MAX_V];
5  //To add an edge use
6  #define add(a, b, w) G[a].pb(mkp(w, b))
7
8  ll dijkstra(int s, int t){//O(|E| log |V|)
9      priority_queue<ii, vector<ii>, greater<ii> > Q;
10     vector<ll> dist(N, INF); vector<int> dad(N, -1);
11     Q.push(mkp(0, s)); dist[s] = 0;
12     while(sz(Q)){
13         ii p = Q.top(); Q.pop();
14         if(p.snd == t) break;
15         forall(it, G[p.snd])
16             if(dist[p.snd]+it->first < dist[it->snd]){
17                 dist[it->snd] = dist[p.snd] + it->fst;
18                 dad[it->snd] = p.snd;
19                 Q.push(mkp(dist[it->snd], it->snd));
20             }
21     }
22     return dist[t];
23     if(dist[t]<INF)//path generator
24         for(int i=t; i!=-1; i=dad[i])
25             printf("%d%c", i, (i==s?' \n':' \u'));
26 }

```

7.2. Bellman-Ford

```

1  vector<ii> G[MAX_N]; //ady. list with pairs (weight, dst)
2  int dist[MAX_N];
3  void bford(int src){//O(VE)
4      dist[src]=0;
5      forn(i, N-1) forn(j, N) if(dist[j]!=INF) forall(it, G[j])
6          dist[it->snd]=min(dist[it->snd], dist[j]+it->fst);

```



```

7 }
8
9 bool hasNegCycle(){
10     forn(j, N) if(dist[j]!=INF) forall(it, G[j])
11         if(dist[it->snd]>dist[j]+it->fst) return true;
12     //inside if: all points reachable from it->snd will have -INF distance
13     (do bfs)
14     return false;
15 }

```

7.3. Floyd-Warshall

```

1 //G[i][j] contains weight of edge (i, j) or INF
2 //G[i][i]=0
3 int G[MAX_N][MAX_N];
4 void floyd(){//O(N^3)
5     forn(k, N) forn(i, N) if(G[i][k]!=INF) forn(j, N) if(G[k][j]!=INF)
6         G[i][j]=min(G[i][j], G[i][k]+G[k][j]);
7 }
8 bool inNegCycle(int v){
9     return G[v][v]<0;}
10 //checks if there's a neg. cycle in path from a to b
11 bool hasNegCycle(int a, int b){
12     forn(i, N) if(G[a][i]!=INF && G[i][i]<0 && G[i][b]!=INF)
13         return true;
14     return false;
15 }

```

7.4. Kruskal

```

1 struct Ar{int a,b,w;};
2 bool operator<(const Ar& a, const Ar &b){return a.w<b.w;}
3 vector<Ar> E;
4 ll kruskal(){
5     ll cost=0;
6     sort(E.begin(), E.end()); //ordenar aristas de menor a mayor
7     uf.init(n);
8     forall(it, E){
9         if(uf.comp(it->a)!=uf.comp(it->b)){//si no estan conectados
10             uf.unir(it->a, it->b); //conectar
11             cost+=it->w;
12         }
13     }
14     return cost;

```

```

15 }

```

7.5. Prim

```

1 bool taken[MAXN];
2 priority_queue<ii, vector<ii>, greater<ii> > pq; //min heap
3 void process(int v){
4     taken[v]=true;
5     forall(e, G[v])
6         if(!taken[e->second]) pq.push(*e);
7 }
8
9 ll prim(){
10     zero(taken);
11     process(0);
12     ll cost=0;
13     while(sz(pq)){
14         ii e=pq.top(); pq.pop();
15         if(!taken[e.second]) cost+=e.first, process(e.second);
16     }
17     return cost;
18 }

```

7.6. 2-SAT + Tarjan SCC

```

1 //We have a vertex representing a var and other for his negation.
2 //Every edge stored in G represents an implication. To add an equation
3 //of the form a|b, use addor(a, b)
4 //MAX=max cant var, n=cant var
5 #define addor(a, b) (G[neg(a)].pb(b), G[neg(b)].pb(a))
6 vector<int> G[MAX*2];
7 //idx[i]=index assigned in the dfs
8 //lw[i]=lowest index(closer from the root) reachable from i
9 int lw[MAX*2], idx[MAX*2], qidx;
10 stack<int> q;
11 int qcmp, cmp[MAX*2];
12 //verdad[cmp[i]]=valor de la variable i
13 bool verdad[MAX*2+1];
14
15 int neg(int x) { return x>=n? x-n : x+n;}
16 void tjn(int v){
17     lw[v]=idx[v]=++qidx;
18     q.push(v), cmp[v]=-2;
19     forall(it, G[v]){

```

```

19     if(!idx[*it] || cmp[*it]==-2){
20         if(!idx[*it]) tjn(*it);
21         lw[v]=min(lw[v], lw[*it]);
22     }
23 }
24 if(lw[v]==idx[v]){
25     qcmp++;
26     int x;
27     do{x=q.top(); q.pop(); cmp[x]=qcmp;}while(x!=v);
28     verdad[qcmp]=(cmp[neg(v)]<0);
29 }
30 }
31 //remember to CLEAR G!!!
32 bool satisf(){//O(n)
33     memset(idx, 0, sizeof(idx)), qidx=0;
34     memset(cmp, -1, sizeof(cmp)), qcmp=0;
35     forn(i, n){
36         if(!idx[i]) tjn(i);
37         if(!idx[neg(i)]) tjn(neg(i));
38     }
39     forn(i, n) if(cmp[i]==cmp[neg(i)]) return false;
40     return true;
41 }

```

7.7. Articulation Points

```

1 int N;
2 vector<int> G[1000000];
3 //V[i]=node number(if visited), L[i]= lowest V[i] reachable from i
4 int qV, V[1000000], L[1000000], P[1000000];
5 void dfs(int v, int f){
6     L[v]=V[v]=++qV;
7     forall(it, G[v])
8         if(!V[*it]){
9             dfs(*it, v);
10            L[v] = min(L[v], L[*it]);
11            P[v]+= L[*it]>=V[v];
12        }
13     else if(*it!=f)
14         L[v]=min(L[v], V[*it]);
15 }
16 int cantart(){ //O(n)
17     qV=0;

```

```

18     zero(V), zero(P);
19     dfs(1, 0); P[1]--;
20     int q=0;
21     forn(i, N) if(P[i]) q++;
22     return q;
23 }

```

7.8. LCA + Climb

```

1 //f[v][k] holds the 2^k father of v
2 //L[v] holds the level of v
3 int N, f[100001][20], L[100001];
4 void build(){//f[i][0] must be filled previously, O(nlgn)
5     forn(k, 20-1) forn(i, N) f[i][k+1]=f[f[i][k]][k];}
6
7 #define lg(x) (31-__builtin_clz(x))//=floor(log2(x))
8
9 int climb(int a, int d){//O(lgn)
10     if(!d) return a;
11     dforn(i, lg(L[a])+1)
12         if(1<<i<=d)
13             a=f[a][i], d-=1<<i;
14     return a;
15 }
16 int lca(int a, int b){//O(lgn)
17     if(L[a]<L[b]) swap(a, b);
18     a=climb(a, L[a]-L[b]);
19     if(a==b) return a;
20     dforn(i, lg(L[a])+1)
21         if(f[a][i]!=f[b][i])
22             a=f[a][i], b=f[b][i];
23     return f[a][0];
24 }

```

8. Network Flow

8.1. Dinic

```

1 int nodes, src, dest;
2 int dist[MAX], q[MAX], work[MAX];
3
4 struct Edge {
5     int to, rev;

```

```

6   ll f, cap;
7   Edge(int to, int rev, ll f, ll cap) : to(to), rev(rev), f(f), cap(cap)
    {}
8 };
9
10 vector<Edge> G[MAX];
11
12 // Adds bidirectional edge
13 void addEdge(int s, int t, ll cap){
14     G[s].push_back(Edge(t, G[t].size(), 0, cap));
15     G[t].push_back(Edge(s, G[s].size()-1, 0, 0));
16 }
17
18 bool dinic_bfs() {
19     fill(dist, dist + nodes, -1);
20     dist[src] = 0;
21     int qt = 0;
22     q[qt++] = src;
23     for (int qh = 0; qh < qt; qh++) {
24         int u = q[qh];
25         forall(e, G[u]){
26             int v = e->to;
27             if(dist[v]<0 && e->f < e->cap){
28                 dist[v]=dist[u]+1;
29                 q[qt++]=v;
30             }
31         }
32     }
33     return dist[dest] >= 0;
34 }
35
36 ll dinic_dfs(int u, ll f) {
37     if (u == dest) return f;
38     for (int &i = work[u]; i < (int) G[u].size(); i++) {
39         Edge &e = G[u][i];
40         if (e.cap <= e.f) continue;
41         int v = e.to;
42         if (dist[v] == dist[u] + 1) {
43             ll df = dinic_dfs(v, min(f, e.cap - e.f));
44             if (df > 0) {
45                 e.f += df;
46                 G[v][e.rev].f -= df;
47                 return df;

```

```

48     }
49 }
50 }
51 return 0;
52 }
53
54 ll maxFlow(int _src, int _dest) { //O(V^2 E)<
55     src = _src;
56     dest = _dest;
57     ll result = 0;
58     while (dinic_bfs()) {
59         fill(work, work + nodes, 0);
60         while(ll delta = dinic_dfs(src, INF))
61             result += delta;
62     }
63     return result;
64 }

```

8.2. Edmonds Karp's

```

1  #define MAX_V 1000
2  #define INF 1e9
3  //special nodes
4  #define SRC 0
5  #define SNK 1
6  map<int, int> G[MAX_V]; //limpiar esto
7  //To add an edge use
8  #define add(a, b, w) G[a][b]=w
9  int f, p[MAX_V];
10 void augment(int v, int minE){
11     if(v==SRC) f=minE;
12     else if(p[v]!==-1){
13         augment(p[v], min(minE, G[p[v]][v]));
14         G[p[v]][v]-=f, G[v][p[v]]+=f;
15     }
16 }
17 ll maxflow(){ //O(VE^2)
18     ll Mf=0;
19     do{
20         f=0;
21         char used[MAX_V]; queue<int> q; q.push(SRC);
22         zero(used), memset(p, -1, sizeof(p));
23         while(sz(q)){

```

```

24     int u=q.front(); q.pop();
25     if(u==SNK) break;
26     forall(it, G[u])
27         if(it->snd>0 && !used[it->fst])
28             used[it->fst]=true, q.push(it->fst), p[it->fst]=u;
29     }
30     augment(SNK, INF);
31     Mf+=f;
32 }while(f);
33 return Mf;
34 }

```

8.3. Push-Relabel

```

1  #define MAX_V 1000
2  int N;//valid nodes are [0...N-1]
3  #define INF 1e9
4  //special nodes
5  #define SRC 0
6  #define SNK 1
7  map<int, int> G[MAX_V];
8  //To add an edge use
9  #define add(a, b, w) G[a][b]=w
10 ll excess[MAX_V];
11 int height[MAX_V], active[MAX_V], count[2*MAX_V+1];
12 queue<int> Q;
13 void enqueue(int v) {
14     if (!active[v] && excess[v] > 0) active[v]=true, Q.push(v); }
15 void push(int a, int b) {
16     int amt = min(excess[a], ll(G[a][b]));
17     if(height[a] <= height[b] || amt == 0) return;
18     G[a][b]-=amt, G[b][a]+=amt;
19     excess[b] += amt, excess[a] -= amt;
20     enqueue(b);
21 }
22 void gap(int k) {
23     forn(v, N){
24         if (height[v] < k) continue;
25         count[height[v]]--;
26         height[v] = max(height[v], N+1);
27         count[height[v]]++;
28         enqueue(v);
29     }

```

```

30 }
31 void relabel(int v) {
32     count[height[v]]--;
33     height[v] = 2*N;
34     forall(it, G[v])
35         if(it->snd)
36             height[v] = min(height[v], height[it->fst] + 1);
37     count[height[v]]++;
38     enqueue(v);
39 }
40 ll maxflow() { //O(V^3)
41     zero(height), zero(active), zero(count), zero(excess);
42     count[0] = N-1;
43     count[N] = 1;
44     height[SRC] = N;
45     active[SRC] = active[SNK] = true;
46     forall(it, G[SRC]){
47         excess[SRC] += it->snd;
48         push(SRC, it->fst);
49     }
50     while(sz(Q)) {
51         int v = Q.front(); Q.pop();
52         active[v]=false;
53         forall(it, G[v]) push(v, it->fst);
54         if(excess[v] > 0)
55             count[height[v]] == 1? gap(height[v]):relabel(v);
56     }
57     ll mf=0;
58     forall(it, G[SRC]) mf+=G[it->fst][SRC];
59     return mf;
60 }

```

9. Ayudamemoria

Límites

```

1  #include <climits> //INT_MIN, LONG_MAX, ULLONG_MAX, etc.

```

Cant. decimales

```

1  #include <iomanip>
2  cout << setprecision(2) << fixed;

```

Rellenar con espacios(para justificar)

```
1 | #include <iomanip>
2 | cout << setfill(' ') << setw(3) << 2 << endl;
```

Leer hasta fin de línea

```
1 | #include <sstream>
2 | //hacer cin.ignore() antes de getline()
3 | while(getline(cin, line)){
4 |     istringstream is(line);
5 |     while(is >> X)
6 |         cout << X << " ";
7 |     cout << endl;
8 | }
```

Aleatorios

```
1 | #define RAND(a, b) (rand()%(b-a+1)+a)
2 | srand(time(NULL));
```

Doubles Comp.

```
1 | const double EPS = 1e-9;
2 | x == y <=> fabs(x-y) < EPS
3 | x > y <=> x > y + EPS
4 | x >= y <=> x > y - EPS
```

Límites

```
1 | #include <limits>
2 | numeric_limits<T>
3 |     ::max()
4 |     ::min()
5 |     ::epsilon()
```

Muahaha

```
1 | #include <signal.h>
2 | void divzero(int p){
3 |     while(true);}
4 | void segm(int p){
5 |     exit(0);}
6 | //in main
7 | signal(SIGFPE, divzero);
8 | signal(SIGSEGV, segm);
```

Mejorar velocidad

```
1 | ios::sync_with_stdio(false);
```

Mejorar velocidad 2

```
1 | //Solo para enteros positivos
2 | inline void Scanf(int& a){
3 |     char c = 0;
4 |     while(c<33) c = getc(stdin);
5 |     a = 0;
6 |     while(c>33) a = a*10 + c - '0', c = getc(stdin);
7 | }
```

Leer del teclado

```
1 | freopen("/dev/tty", "a", stdin);
```

File setup

```
1 | //tambien se pueden usar comas: {a, x, m, l}
2 | for i in {a..k}; do cp template.cpp $i.cpp; touch $i.in; done
```